AD-A103 311 RAND CORP SANTA MONICA CA F/G 5/10
SELECTED RESEARCH PUBLICATIONS IN COGNITIVE SCIENCE BY RAND STA--ETC(U)
FEB 81 S GOLDIN, B HAYES-ROTH, F HAYES-ROTH
UNCLASSIFIED RAND/P-5950/12 NL

LEVEL II

(1)

SELECTED RESEARCH PUBLICATIONS IN COGNITIVE SCIENCE BY RAND STAFF: 1979-1980

S. Goldin, B. Hayes-Roth, F. Hayes-Roth, P. Klahr, D. McArthur, C. Stasz, P. Thorndyke, C. Veit, D. Waterman, K. Wescourt, R. Wesson

February 1981

Sarah ~~Sara~~ /Goldin, Barbara /Hayes-Roth, Frederick /Hayes-Roth, Philip /Klahr, Dave /McArthur

P-5950/2

ERRÀTA

P-5950/2 SELECTED RESEARCH PUBLICATIONS IN COGNITIVE SCIENCE BY RAND STAFF: 1979-1980

p.6, Number 122., first line (title) — Change syntaxy to imagery. Title should read Understanding mental imagery(not Understanding mental syntaxy).

PUBLICATIONS DEPARTMENT

Rand
SANTA MONICA, CA. 90406

The Rand Corporation
Santa Monica, California 90406

PREFACE

The bibliography presented on the following pages is a compilation of recent publications by some of the Rand researchers in the Information Processing Systems research program. The bibliography is selective, comprising only those papers concerned with the broad range of topics in Cognitive Science. These topics include the modeling of complex human behaviors, the construction of intelligent computer systems, and the representation of knowledge in human and computer memories. The research draws upon the disciplines of cognitive psychology, educational psychology, computer science, artificial intelligence, and linguistics.

The bibliography is organized into two sections. The first section contains abstracts for papers published between April 1979 and December 1980. The second section contains a list of titles published prior to April 1979. Rand Papers P-5950 and P-5950/1 contain abstracts for these earlier papers.

The titles are organized alphabetically, with an author index following the list of publications. The Rand researchers represented in this bibliography are Sarah Goldin, Barbara Hayes-Roth, Frederick Hayes-Roth, Philip Klahr, Dave McArthur, Cathleen Stasz, Perry Thorndyke, Don Waterman, Clairice Veit, Keith Wescourt, and Robert Wesson. Requests for reprints of Rand publications may be addressed to the Rand Publications Department, 1700 Main Street, Santa Monica, California 90406. Requests for reprints of journal articles or book chapters should be addressed directly to the author.

RESEARCH IN COGNITIVE SCIENCE BY RAND STAFF: 1979-1980

109. Erman, L. D., Hayes-Roth, F., Lesser, V. R., and Reddy, D. R. The Hearsay-II speech-understanding system: Integrating knowledge to resolve uncertainty. Computing Surveys, Vol. 12, No. 2, June 1980.

The Hearsay-II system, developed during the DARPA-sponsored five-year speech-understanding research program, represents both a specific solution to the speech-understanding problem and a general framework for coordinating independent processes to achieve cooperative problem-solving behavior. Discussed in this paper are the characteristics of the speech problem in particular, the special kinds of problem-solving uncertainty in that domain, the structure of the Hearsay-II system developed to cope with that uncertainty, and the relationship between Hearsay-II's structure and those of other speech-understanding systems. The paper is intended for the general computer science audience and presupposes no speech or artificial intelligence background.

110. Faught, W. S., Klahr, P., and Martins, G. R. An artificial intelligence approach to large-scale simulation. Proceedings of the 1980 Summer Simulation Conference, Seattle, 1980, 231-236.

The authors present a new approach to the design of large-scale simulators. Techniques developed in the area of Artificial Intelligence, particularly in the development of "expert systems," are relevant to the design of simulators that model decision-making behavior. They have adapted and extended these techniques in ROSS, a Rule-Oriented Simulation System that simulates air penetration battles.

111. Faught, W. S., Waterman, D. A., Rosenschein, S. J., Gorlin, D. M., and Tepper, S. J. EP-2, A prototype exemplary programming system. Proceedings of the ACM Annual Conference, Detroit, 1979, 135-142.

This report describes the design and implementation of the Exemplary Programming (EP) system that allows software to be created by example. The EP paradigm is as follows: The user performs some interactive task on a computer. The EP system watches over the user's shoulder, recording the interaction between the user and the system he is using. When the task is done, EP constructs an algorithm or high-level model of the interaction. Part of this construction may involve questions to the user or advice from the user. EP constructs a program (agent) from the

model and stores it in a library for subsequent use. A critique and suggestions for the next version of the EP system are included.

112. Goldin, S. E., and Thorndyke, P. W. (Eds.). Improving team performance: Proceedings of the Rand Team Performance Workshop. Rand Report R-2606-ONR, August 1980.

This paper reports the proceedings of the Rand Workshop on Team Performance sponsored by the Office of Naval Research. This workshop considered options for future research on teams from the perspectives of a number of different disciplines. Experts in the domains of gaming and simulation, organizational theory, small group processes, cognitive psychology, training and instruction, decision theory, heuristic modeling and human engineering presented views on potential contributions of their disciplines to team research. Discussions among workshop participants focused on a range of issues, including current problems in the performance of Navy teams, the desirability of studying teams in their operational environments, the need for specifying training objectives prior to instructional design, and the need for designing team research programs prior to establishing a dedicated team research facility. A number of broad areas seems to offer promise for future research: team performance requirements, team structure, team communications, training techniques, and organizational determinants of team performance.

113. Hayes-Roth, B. Estimation of time requirements during planning: Interactions between motivation and cognition. Rand Note N-1581-ONR, November 1980.

Human planners show a strong tendency to underestimate the time required for planned tasks. In addition, time stress increases this tendency. The more difficult it is to accomplish all tasks under consideration in the available time, the stronger the tendency to underestimate time requirements. In addition to documenting these effects, this Note provides evidence for two underlying factors. A cognitive factor refers to people's tendency to plan at high levels of abstraction. Because they fail to enumerate all time-consuming components of planned tasks, they systematically underestimate the time required to perform the tasks as wholes. A motivational factor refers to people's desire to accomplish all or most of the tasks under consideration. This motivation biases them to underestimate required times. The Note concludes with a discussion of methods for correcting underestimation of time requirements during planning.

114. Hayes-Roth, B. Flexibility in executive strategies. Rand Note N-1170-ONR, September 1980.

Executive strategies determine the allocation of cognitive resources during problem-solving. Earlier research has suggested that people can adopt alternative strategies for solving particular problems. This paper examines an "opportunistic" model of executive strategies and evaluates some of its predictions for performance of an errand-planning task. Five experiments confirmed that (a) people can adopt different strategies for this task; (b) people can learn new strategies from explicit instruction or from experience; (c) problem characteristics can influence which strategy people adopt; and (d) adopted strategy interacts with problem characteristics to determine planning time and number and importance of planned errands. The results also suggested that some people have a proclivity to adopt a particular strategy and resist adopting a new one. Implications of the results and desirable properties of the model are discussed.

115. Hayes-Roth, B. Projecting the future for situation assessment and planning: A cognitive analysis. Rand Note N-1600-AF, November 1980

Situation assessment and planning rely heavily on the decisionmaker's ability to project future conditions in the environment and the impact of tentative planned actions on those conditions. This Note presents a cognitive analysis of the future projection process. It identifies three projection strategies--retrieval from experience, formal analysis, and mental simulation--and characterizes their strengths and weaknesses. It also discusses the impact of three general cognitive factors--operation at different levels of abstraction, motivational factors, and attribution problems--on the future projection process. Based on this analysis, the Note proposes a cognitive technology for developing and training effective future projection processes.

116. Hayes-Roth, B., with S. Cammarata, S. E. Goldin, F. Hayes-Roth, S. Rosenschein, and P. W. Thorndyke. Human planning processes. Rand Report R-2670-ONR, November 1980.

This Report summarizes a three-year research project investigating the cognitive processes underlying human planning behavior. The project focused on problems analogous to the naval tactical planning problem: How should the decisionmaker move force units from their current locations to particular task force objectives? Major project tasks included: developing a cognitive model of the planning process, implementing the model as a

computer simulation and evaluating its performance, conducting empirical research to test the basic assumptions of the model and to identify important task and individual difference factors that impact on the planning process. Based on the results of these research efforts, the project produced a preliminary set of guidelines for improving the selection and training of planners and for designing effective planning aids.

117. Hayes-Roth, B., and Goldin, S. Individual differences in planning processes. Rand Note N-1488-ONR, June 1980.

This Note reports an initial investigation of individual differences in planning. The research reported here focuses on the analysis of thinking-aloud protocols produced by five subjects as they performed a set of errand-planning tasks. The protocols were coded into content categories suggested by the opportunistic planning model developed by Hayes-Roth and Hayes-Roth (1979). Final plans were evaluated against a set of normative criteria, such as route efficiency and temporal realism. Then the occurrence of various content categories in the protocols was related to individual subjects' planning scores in an effort to describe patterns of category usage that correlated with planning skill.

This analysis highlighted a number of differences between good and poor planners. Good planners used the available set of decision categories more extensively than poor planners. In particular, good planners made more decisions establishing criteria for plan generation and evaluation, more decisions controlling allocation of cognitive resources during planning, and more decisions assessing data relevant to planned actions. Good planners also made more decisions at higher levels of abstraction, especially decisions concerning the intended outcomes of the plan and decisions concerning an overall temporal-spatial design for the plan.

Good planners also differed from poor planners in the detailed content of their decisions. They more frequently reviewed and evaluated previous decisions. They were more likely to compare alternative plan actions. They were more sensitive to constraints on when certain errands could be done and to the existence of spatial clusters of errands. They had larger repertoires of decision types governing general plan characteristics. They generated a greater number and variety of decisions determining the focus of attention. Finally, although good planners and poor planners used essentially the same criteria for generating and evaluating their plans, good planners used most of these criteria more frequently than did poor planners.

118. Hayes-Roth, B., and Hayes-Roth, F. A cognitive model of planning. Cognitive Science, Vol. 3, 1979, 275-310.

This paper presents a cognitive model of the planning process. The model generalizes the theoretical architecture of the Hearsay-II system. Thus, it assumes that planning comprises the activities of a variety of cognitive "specialists." Each specialist can suggest certain kinds of decisions for incorporation into the plan in progress. These include decisions about: (a) how to approach the planning problem; (b) what knowledge bears on the problem; (c) what kinds of actions to try to plan; (d) what specific actions to plan; and (e) how to allocate cognitive resources during planning. Within each of these categories, different specialists suggest decisions at different levels of abstraction. The activities of the various specialists are not coordinated in any systematic way. Instead, the specialists operate opportunistically, suggesting decisions whenever promising opportunities arise. The paper presents a detailed account of the model and illustrates its assumptions with a "thinking aloud" protocol. It also describes the performance of a computer simulation of the model. The paper contrasts the proposed model with successive refinement models and attempts to resolve apparent differences between the two points of view.

119. Hayes-Roth, B., and Thorndyke. P. W. Decisionmaking during the planning process. Rand Note N-1213-ONR, November 1980.

Planning requires an individual to make a series of decisions about an intended course of action. This paper evaluates two major assumptions of an "opportunistic" model of the planning process: (a) that planners make decisions at different levels of abstraction; (b) that prior decisions constrain the choice of subsequent decisions; and (c) that planners generate decision sequences opportunistically. The results of three experiments supported these assumptions. In Experiment 1, subjects' sortings of statements representing different planning decisions confirmed the postulated levels of abstraction. In Experiment 2, particular prior decisions influenced subjects' choice between alternative subsequent decisions. In Experiment 3, different prior decisions influenced subjects to choose subsequent decisions at either higher or lower levels of abstraction.

120. Hayes-Roth, F. Distinguishing theories of representation: A critique of Anderson's "Arguments concerning mental imagery." Psychological Review, 1979, Vol. 86, No. 4, 376-382. Also issued as Rand Paper P-6180, 1978.

In a recent article, Anderson argued that behavioral data could

not distinguish alternative theories of memory representations. The theorem Anderson proved does not support his conclusions. Five fallacies in his argument are criticized: (a) Behavioral data cannot distinguish alternative models; (b) an invertible function relates corresponding states of alternative representation theories; (c) propositional models can account for data supporting image models and thus, warrant equal credibility; (d) propositional descriptions constitute parsimonious models; and (e) unless explicitly operationalized, image models cannot support theoretical or empircal research. Contrary to these beliefs, representational differences can qualitatively affect performance, and such important differences apparently characterize the analog class of imagery models.

121. Hayes-Roth, F. Matching and abstraction in knowledge systems. Rand Paper P-6440, January 1980.

A briefing presented at the Symposium on Artificial Intelligence in Information Science during the 1979 Annual Meeting of the American Society for Information Science (ASIS) in Minneapolis. Discusses the creation of a knowledge system and problems relating to it. Twenty examples are illustrated and discussed providing details on knowledge systems and data representation. Topics include: matching and abstraction in knowledge systems, knowledge bases, information retrieval, partial matches, and future research issues.

122. Hayes-Roth, F. Understanding mental syntaxy: Interpretive metaphors vs. explanatory models, Open Peer Commentary of On the demystification of mental imagery by S. Kosslyn, S. Pinker, G. Smith and S. Shwartz, The Behavioral and Brain Sciences, 1979, Vol. 2, 53-554.

123. Hayes-Roth, F., Klahr, P., and Mostow, D. J. Advice-taking and knowledge refinement: An iterative view of skill acquisition. Rand Paper P-6517, July 1980. (To appear in J. R. Anderson (ed.), Skill acquisition and development, Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1981.)

This paper considers knowledge acquisition and skill development as an iterative process. In the first phase, an initial capability is achieved by understanding instructions and following advice. Once a person (or machine) tries out its new knowledge, a variety of potential problems and learning opportunities arise. These stimulate refinements to previous knowledge which, in turn, reinitiate the entire cycle. This learning paradigm has led to new work in knowledge representation, operationalization, expectation-driven bug detection, and knowledge refinement

techniques. This paper explains how advice is converted into operational behavior, how unexpected or undesirable behavioral outcomes stimulate learning efforts, and how the bugs responsible can be diagnosed and repaired. These phenomena are illustrated with examples of human and machine skill development in a familiar card game. The proposed learning methods provide a basis for a deeper understanding of skilled behavior and its development than previously possible.

124. Hayes-Roth, F., Klahr, P., and Mostow, D. J. Knowledge acquisition, knowledge programming, and knowledge refinement. Rand Report R-2540-NSF, November 1979.

Principal findings and recommendations of a two-year study of machine-aided knowledge acquisition. The report discusses the transfer of expertise from humans to machines, as well as the functions of planning, debugging, knowledge refinement, and autonomous machine learning. The research method emphasizes iterative refinement of knowledge in response to actual experience. A machine's "knowledge" is acquired from a human, who provides concepts, constraints, and problem-solving heuristics to define some minimal level of performance. Semi-automatic methods convert the initial knowledge into a working program whose resulting behaviors can be used to diagnose problems and design refinements. Methods formulated here may reduce or eliminate much of the human involvement currently required in this process. The approach is illustrated by application of the paradigm to the game of hearts. Recommendations suggest increased emphasis on core research problems standing between current technology and the capability of automatic knowledge programming and refinement.

125. Klahr, P. Conditional answers in question-answering systems. Proceedings of the Sixth International Joint Conference on Artificial Intelligence, Tokyo, Japan, 1979, 481-483.

In many cases a deductive question-answering system cannot find complete proofs to answer questions requiring deductive support. In some cases information needed to complete proofs is missing from the knowledge base. In other cases processing limits may have been reached before proofs could be completed. Rather than disregarding such partial proofs as most systems do, the DADM system displays them to users and identifies subproblems that remain unresolved. Answers emanating from partial proofs include remaining subproblems as "conditions" which must be true for the answers to be valid.

126. Klahr, P., and Faught, W. S. Knowledge-based simulation. Proceedings of the First Annual National Conference on Artificial Intelligence, Palo Alto, 1980, 181-183.

Knowledge engineering has been successfully applied in many domains to create knowledge-based "expert" systems. We have applied this technology to the area of large-scale simulation and have implemented ROSS, a Rule-Oriented Simulation System, that simulates military air battles. Alternative decision-making behaviors have been extracted from experts and encoded as object-oriented rules. Browsing of the knowledge and explanation of events occur at various levels of abstraction.

127. Klahr, P., Faught, W. S., and Martins, G. R. Rule-oriented simulation. Proceedings of the International Conference on Cybernetics and Society, Boston, 1980, 350-354.

Large-scale simulators have been plagued with problems of intelligibility, modifiability, credibility and performance. Techniques developed in the area of Artificial Intelligence, particularly in the development of knowledge-based "expert" systems, are relevant to the design of simulators that model decision-making behaviors. We outline the problems we have encountered in large-scale simulation and present an approach that incorporates and extends those techniques. We describe ROSS, a Rule-Oriented Simulation System, that embodies these techniques in the domain of military air battles.

128. Klahr, P., Travis, L., and Kellogg, C. A deductive system for natural-language question answering. In L. Bolc (ed.), Natural language question answering systems, Hanser-Verlag, Munich, 1980, 73-136.

This paper describes a deductive processor designed to enhance the capabilities of the CONVERSE natural-language question-answering system. The emphasis is on deduction within a question-answering context rather than within a mathematical inference system. The deductive processor has been designed to find, for a given input question, the relevant general premises needed for deducing an answer. Selecting relevant premises is most crucial when there exists a very large number of premises, most of which are irrelevant to any particular query. The deductive system first constructs preliminary, skeletal derivation proposals. The purpose of these proposals is to find possible deductions before any attempt is made to verify the proposals. Verification is thus delayed until global proof plans have been established. Later processing phases examine the variable flows (substitutions) within a proposal to detect possible collisions and search the fact file for compatible sets of

values for instantiations. The use of semantic information is incorporated into the system.

129. Lenat, D. B., Hayes-Roth, F., and Klahr, P. Cognitive Economy. Rand Note N-1185-NSF, June 1979.

Intelligent systems can explore only tiny subsets of their potential external and conceptual worlds. To increase their effective capacities, they must develop efficient forms of representation, access, and operation. In this Note we develop several techniques which do not sacrifice expressibility, yet enable programs to (semi-)automatically improve themselves and thus increase their productivity. The basic source of power is the ability to predict the way that the program will be used in the future, and to tailor the program to expedite such uses. Abstraction, caching, and expectation-simplified processing are principal examples of such techniques. We discuss the use of these and other economic principles for modern AI systems. Our analysis leads to some counterintuitive ideas and proposed policies which are not generally followed because their contribution to overall cognitive utility is not readily apparent. For example, we challenge the typical practice of storing properties "economically" in hierarchical inheritance nets. That nonredundant storage practice provides some storage cost savings, but significantly increases processing costs. As an alternative, we suggest storage schemes to improve performance by exploiting various forms of redundancy consistent with general caching heuristics.

130. McArthur, D. Intelligent problem solving in chess. Ph.D Thesis, University of Michigan, November 1980.

131. McArthur, D. Machine vision and human perception. Human Performance Technical Report #82, University of Michigan, January 1980.

132. McArthur, D. Causal reasoning in chess. Cognitive Science Series working Paper, University of Michigan, May 1980.

133. Shavelson, R. J., and Stasz, C. Some methods for representing the structure of concepts in prose material. In J. Hartley (ed.), The psychology of written communication, selected readings. Nichols, New York, 1980.

134. Smith, H. T., Waterman, D. A., and Faught, W. S. An office communication system design. Rand Paper P-6393, September 1979.

135. Stasz, C. Ability and strategy differences in map learning. In M. P. Friedman, J. P. Das and N. O'Connor (eds.), Intelligence and learning, Plenum Press, New York, in press. Also issued as Rand Note N-1569-ONR, August 1980.

This paper describes the influence of individual differences in abilities and subject-selected techniques for learning maps. Verbal protocols were obtained from 25 subjects who differed in psychometrically measured spatial restructuring and visual memory abilities. These protocols suggested a number of learning procedures and strategies that subjects used to focus attention, encode information and evaluate their learning progress while studying a map. High ability subjects differed from low ability subjects in the overall strategies they adopted to approach the learning problem, in their use of imagery for encoding spatial information, and in their subsequent recall of spatial attributes of the map.

136. Stasz, C., and Thorndyke, P. W. The influence of visual spatial ability and study procedures of map learning skill. Rand Note N-1501-ONR, August 1980.

This study investigated two sources of individual differences in map learning: abilities and learning procedures. Twenty-five subjects provided verbal protocols while learning two maps. Visual-spatial ability was highly correlated with recall of spatial attributes of the map and with overall performance, while associative memory ability was most correlated with verbal attribute recall. Successful learners more frequently employed procedures for encoding spatial information and assessing learning progress. However, high and low ability subjects differed little in the study procedures they chose. Although both ability differences and procedure use were important contributors to performance, abilities were the strongest predictors of map learning. We concluded that: (1) using effective study procedures influences map learning, and (2) high ability subjects benefit more from using these procedures than low ability subjects.

137. Thorndyke, P. W. Distance estimation from cognitive maps. Rand Report R-2474-ONR, November 1979.

Four experiments investigated map clutter as a source of distortion in subjects' estimates of distance. In Experiments 1 and 2, subjects estimated distances between pairs of points on a

memorized map. In Experiment 1, they learned relative distances among cities incidentally; in Experiment 2, they learned these distances intentionally. In both experiments, estimates increased as a linear function of the number of intervening points along the judged path. In Experiment 3, subjects estimated distances while viewing the map. With this procedure, the effect of clutter was reduced but not eliminated. In Experiment 4, the clutter effect was demonstrated using subjects' pre-experimental knowledge of U.S. geography. Psychophysical power functions relating true to estimated distance provided a good fit to both memory and perception data. These results suggest an analogy between perceptual and memorial processes of distance estimation. The estimation model providing the best fit to the data assumed that subjects perceptually scan a route (or a mental image of a route) from the starting point to the destination point and use scan duration to determine route distance.

138. Thorndyke, P. W. Performance models for spatial and locational cognition. Rand Report R-2676-ONR, December 1980.

Summarizes a three-year investigation of the knowledge and processes people use to learn and make spatial judgments in large-scale environments. Experiments in map learning indicated that both the use of effective study procedures and visual memory ability determine success at learning a map. All but low-ability people benefit from training in effective study procedures. Studies of people's procedures for accuracy at estimating distances on maps indicated that map clutter increases subjective distance between two points. A third series of studies investigated differences in the knowledge people acquire from navigation and from map learning. Studying a map leads to a global representation of the environment, while navigation provides a linear, or procedural representation. Navigation experience is optimal for estimating route distances and orienting oneself toward unseen locations. Map learning is optimal for estimating the shortest distance between two points and determining relative locations of objects.

139. Thorndyke, P. W. Spatial cognition and reasoning. In J. Harvey (ed.), Cognition, social behavior, and the environment, Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1980.

140. Thorndyke, P. W., and Hayes-Roth, B. Differences in spatial knowledge acquired from maps and navigation. Rand Note N-1595-ONR, November 1980.

This Note proposes models of the spatial knowledge people

acquire from maps and navigation and the procedures required for spatial judgments using this knowledge. From a map, people acquire survey knowledge encoding global spatial relations. This knowledge resides in memory in images that can be scanned and measured like a physical map. From navigation, people acquire procedural knowledge of the routes connecting diverse locations. People combine mental simulation of travel through the environment and informal algebra to compute spatial judgments. An experiment in which subjects learned an environment from navigation or from a map evaluates predictions of these models. With moderate exposure, map learning is superior for judgments of relative location and straight-line distances among objects. Learning from navigation is superior for orienting oneself with respect to unseen objects and estimating route distances. With extensive exposure, the performance superiority of maps over navigation vanishes. These and other results are consonant with the proposed mechanisms.

141. Thorndyke, P. W., and Hayes-Roth, B. Human processing of knowledge from texts: Acquisition, integration, and reasoning. Rand Report R-2256-ARPA, June 1979.

Decisionmakers must frequently assimilate a large number of facts from several documents, organize related facts in memory, and reason using the acquired knowledge. Nine experiments investigated how people learn and retain knowledge in texts and perform inferential reasoning (using several facts to generate or verify conclusions). Individual experiments examined the influence of text structure, the learnability of individual facts, the acquisition of new knowledge conforming to a previously learned structure, the integration of related but separately learned facts in memory, search and verification processes for inferential reasoning, and techniques for improving the organization of information in memory. Results are presented in the context of models for knowledge representation and processing. A set of principles for improving human learning are derived, including text formats that facilitate knowledge acquisition and integration.

142. Thorndyke, P. W., and Stasz, C. Individual differences in procedures for knowledge acquisition from maps. Cognitive Psychology, 1980, Vol. 12, 137-175.

This study investigated the procedures subjects use to acquire knowledge from maps. In Experiment 1, three experienced and five novice map users provided verbal protocols while attempting to learn a map. The protocols suggested four categories of processes that subjects invoked during learning: attention, encoding, evaluation, and control. Good learners differed from

poor learners primarily in their techniques for and success at encoding spatial information, their ability to accurately evaluate their learning progress, and their ability to focus attention on unlearned information. An analysis of the performance of experienced map users suggested that learning depended on particular procedures and not on familiarity with the task. In Experiment 2, subjects were instructed to use (a) six of the effective learning procedures from Experiment 1, (b) six procedures unrelated to learning success, or (c) their own techniques. The effective procedures set comprised three techniques for learning spatial information, two techniques for using self-generated feedback to guide subsequent study behaviors, and a procedure for partitioning the map into sections. Subjects using these procedures performed better than subjects in the other groups. In addition, subjects' visual memory ability predicted the magnitude of the performance differential.

143. Thorndyke, P. W., and Weiner, M. Improving the training and performance of Navy teams: Design for a research program. Rand Report R-2607, July 1980.

A design for a large-scale research program on improving Navy team effectiveness. The report assesses the most critical Navy teams, identifies deficiencies in the performance of these teams, and recommends new research that could lead to significant improvements in team performance. The major conclusions are (1) teams performing time-stressed decisionmaking using symbolic information are most critical to mission effectiveness and ship survivability, (2) several currently available instructional methods could immediately improve training, (3) new interdisciplinary research should study simulated teams in laboratory task environments that provide computer-controlled task scenarios, realistic environmental and enemy models, and intra-team communications networks, and (4) promising approaches to improving teams include improving performance models of team tasks, improving the tools and methods of training, compensating for disruptive effects of turnover in team personnel, improving team organization, and improving human-machine systems to aid task performance.

144. Veit, Clairice T. Analyzing "ratio" and "difference" judgments: A reply to Rule and Curtis. Journal of Experimental Psychology: General, 1980, Vol. 109, No. 3, 301-303.

This Note responds to the speculations of Rule and Curtis that two operations may underlie Veit's "ratio" and "difference" data. Rule and Curtis attempted to simulate Veit's data by the theory that judges perform two operations corresponding to task instructions. They were able to transform both differences and ratios by separate weak monotonic transformations to the same

order and scale. From this they concluded that Veit's data may have been so generated and thus her conclusion that respondents use only one operation for "ratios" and "differences" is suspect. However, reanalysis shows that the simulated data do not approximate Veit's data and that Veit's techniques would have led to a correct diagnosis of Rule and Curtis's simulated data. Other theories postulated by Rule and Curtis that experimental procedures may influence rank orders of "differences" and "ratios" so as to cancel the expected nonmonotonic relationship between the two response matrices are also discussed.

145. Waterman, D. A. Rule-based expert systems. Rand Paper P-6545, September 1980.

146. Waterman, D. A. User-oriented systems for capturing expertise: A rule-based approach. In D. Michie (ed.), Expert systems in the micro-electronic age, 1979.

User-oriented systems for capturing expertise are discussed and illustrated within the context of RITA and ROSIE, two rule-based systems developed for building intelligent interfaces and modeling expert knowledge. RITA, the Rule-Directed Interactive Transaction Agent system is operational and is currently being applied to interface and modeling problems. ROSIE, the Rule-Oriented System for Implementing Expertise, is now under development, and is intended as a tool for model builders working in complex domains for which useful analytic models are unavailable. This note is designed to promote discussion with colleagues interested in rule-based heuristic modeling and is intended for a technical audience.

147. Waterman, D. A., Anderson, R., Hayes-Roth, F., Klahr, P., Martins, G., and Rosenschein, S. Design of a rule-oriented system for implementing expertise. Rand Note N-1158-1-ARPA, May 1979.

This Note describes the preliminary design of a Rule-Oriented System for Implementing Expertise (ROSIE). This system is intended as a tool for model builders seeking to apply expert knowledge to the analysis of problems and to the evaluation of solutions in complex domains, especially domains for which useful analytic models are unavailable.

This preliminary design is the result of a six-month design exercise, and formed the basis of a proposal for implementation of this software system submitted to the Information Processing Techniques Office of the Defense Advanced Research Projects Agency. This Note is being distributed to promote discussion and exchange of views with colleagues interested in rule-

directed systems for heuristic modeling. It is intended for a technical audience; basic knowledge of the architecture of rule-based systems is assumed.

148. Waterman, D. A., Faught, W. S., Klahr, P., Rosenschein, S. J., and Wesson, R. Design issues for exemplary programming. Rand Note N-1484-RC, April 1980.

This report describes the design and implementation of the Exemplary Programming (EP) system that allows software to be created by example. The EP paradigm is as follows: The user performs some interactive task on a computer. The EP system watches over the user's shoulder, recording the interaction between the user and the system he is using. When the task is done, EP constructs an algorithm or high-level model of the interaction. Part of this construction may involve questions to the user or advice from the user. EP then constructs a program (agent) from the model and stores it in a library for subsequent use. A critique and suggestions for the next version of the EP system are included.

149. Waterman, D. A., and Peterson, M., Rule-based models of legal expertise. AAAI Conference Proceedings, August 1980, 272-275.

This paper discusses the design, implementation and testing of a prototype legal decisionmaking system (LDS). This system is being implemented in ROSIE, a rule-oriented language designed to facilitate the development of large expert systems. The effect of changes in the legal system on settlement decisions are studied by modifying the rules representing formal legal doctrine and noting the effect on settlement outcomes. Our current implementation of LDS consists of approximately 90 rules representing negligence and liability laws. Given a description of a product liability case the model attempts to determine what theory of liability applies, whether or not the defendant is liable, how much the case is worth, and what an equitable value for settlement would be. Our preliminary work with LDS has demonstrated the feasibility of applying rule-based modeling techniques to the product liability area. Both the basic concepts needed to describe the domain and the rules required to represent legal doctrine and strategies can be adequately represented in a rule-based formalism such as ROSIE.

150. Wesson, R. B., and Hayes-Roth, F., with J. Burge, C. Stasz, and C. Sunshine. Network structures for distributed situation assessment. Rand Report R-2560-ARPA, August 1980. Also in IEEE Journal of Systems, Man, and Cybernetics. May 1980.

An investigation of potential organizations for automated distributed sensor networks, i.e., dispersed nodes that can pool their information to perform accurate situation assessment. Laboratory experiments using a message puzzle task indicate that an "anarchic committee" organization, in which all nodes communicate with one another, consistently outperforms the "dynamic hierarchical cone" organization, in which communication is constrained and information must be obtained only from lower-level nodes. These experiments support the contention that DSNs must emphasize cooperative problem-solving rather than problem-reduction or subgoaling. A computer-based design that minimizes redundant communications in hierarchical organizations by using model-based reasoning to form expectations that guide, limit, and reduce reporting frequency is described. Finally, a method for representing hypotheses to minimize communication requirements--the process assembly network--is suggested. This concept uses active "hypotheses processes" that are responsible for predicting their own evolution over time.

151. Yekovich, R., and Thorndyke, P. An evaluation of alternative functional models of narrative schemata. Rand Paper P-6299, 1980.

This paper comparatively evaluates several models of how people encode and retrieve information from short narrative texts. The models are distinguished by their detailed assumptions on each of four issues: (1) whether or not propositions are encoded with differential probability as a function of their importance in a narrative structure, (2) whether the representation of the text in memory is hierarchical or heterarchical, (3) whether memory retrieval depends primarily on direct access or on a top-down search process, and (4) whether or not lexical information is retained in memory. Specific assumptions are combined to form twenty alternative memory models. These models are evaluated in an experiment in which subjects attempted to learn four narrative texts. Memory for the texts was tested by both recall and recognition either immediately or after a one-hour delay. Propositional recall, but not recognition, varied as a function of importance. Further, on the recognition test subjects were able to distinguish statements that had occurred in the texts from meaning-preserving paraphrases of these statements. These data suggest that (1) subjects retain lexical information in memory, (2) narrative schemata provide a framework for encoding all text propositions, (3) these schemata are hierarchically organized, and (4) the schemata are used for top-down retrieval of information at output time.

RESEARCH IN COGNITIVE SCIENCE BY RAND STAFF: 1975-1979

1. Anderson, R. H., Gallegos, M., Gillogly, J. J., Greenberg, R., and Villanueva, R. The RITA reference manual. Rand Report R-1808-ARPA, 1977.

2. Anderson, R. H., and Gillogly, J. J. The RAND intelligent terminal agent (RITA) as a network access aid. AFIPS Proceedings, Vol. 45, 1976, 501-509.

3. Anderson, R. H., and Gillogly, J. J. The RAND intelligent terminal agent (RITA): Design philosophy. Rand Report R-1809-ARPA, 1976.

4. Anderson, R. H., and Shapiro, N. Design considerations for a computer-based interactive map display system. Rand Report R-2382-ARPA, 1979.

5. Atkinson, R. C., and Wescourt, K. T. Some remarks on a theory of memory. In P.M.A. Rabbitt and S. Dornic (eds.), Attention and performance, V, Academic Press, London, 1975.

6. Beard, M., Barr, A., Gould, L., and Wescourt, K. T. Curriculum information networks for computer-assisted instruction. Technical Report TR 78-18, Navy Personnel Research and Development Center, San Diego, California, April 1978.

7. Burge, J., and Hayes-Roth, F. A novel pattern of learning and classification procedure applied to the learning of vowels. Proceedings of the I.E.E.E. International Conference on Acoustics, Speech and Signal Processing, 1976, 154-157.

8. Dent, C., and Thorndyke, P. Children's use of schemata in learning narrative discourse. Rand Paper P-6318, 1979.

9. Erman, L. D., Hayes-Roth, F., Lesser, V. R., and Reddy, D. R. A functional description of the Hearsay-II speech understanding system. Speech understanding systems: Summary of results of the five-year research effort. Department of Computer Science, Carnegie-Mellon University, 1976.

10. Fox, M. S., and Hayes-Roth, F. Approximation techniques for the learning of sequential symbolic patterns. Proceedings of the Third International Joint Conference on Pattern Recognition, Coronado, California, 1976.

11. Goldin, S. E. Effects of orienting tasks on recognition of chess positions. American Journal of Psychology, Vol. 91, 1978, 659-671.

12. Goldin, S. E. Memory for the ordinary: Typicality effect in chess memory. Journal of Experimental Psychology: Human Learning and Memory, 1978, Vol. 4, No. 6, 606-616.

13. Goldin, S. E. Facial stereotypes as cognitive categories. Unpublished Ph.D. Thesis, Carnegie-Mellon University, 1979.

14. Goldin, S. E. Recognition memory for chess positions: Some preliminary research. American Journal of Psychology, 1979, Vol. 92, No. 1, 19-31.

15. Hayes, J. R., Waterman, D. A., and Robinson, C. S. Identifying the relevant aspects of a problem text. Cognitive Science, 1977, Vol. 1, 297-314.

16. Hayes-Roth, B. Evolution of cognitive structures and processes. Psychological Review, 1977, Vol. 84, 260-278. Also issued as Rand Paper P-5742, October 1976.

17. Hayes-Roth, B. Implications of human pattern processing for the design of artificial knowledge systems. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems, Academic Press, New York, 1978. Also issued as Rand Paper P-5854, April 1977.

18. Hayes-Roth, B. Structurally integrated versus structurally segregated memory representations: Implications for the design of instructional materials. In A. Lesgold, J. Pellegrino, S. Fokkema, and R. Glaser (eds.), Cognitive psychology and instruction, Plenum, New York, 1978. Also issued as Rand Paper P-5841.

19. Hayes-Roth, B., and Hayes-Roth, F. Plasticity in memorial networks. Journal of Verbal Learning and Verbal Behavior, 1975, Vol. 14, 506-522.

20. Hayes-Roth, B., and Hayes-Roth, F. A comparative psychological investigation of pattern classification theories. Proceedings of the Third International Joint Conference on Pattern Recognition, Coronado, California, 1976.

21. Hayes-Roth, B., and Hayes-Roth, F. Concept learning and the recognition and classification of exemplars. Journal of Verbal Learning and Verbal Behavior, 1977, Vol. 16, 321-338. Also issued as Rand Paper P-5778.

22. Hayes-Roth, B., and Hayes-Roth, F. The prominence of lexical information in memory representations of meaning. Journal of Verbal Learning and Verbal Behavior, 1977, Vol. 16, 1-18.

23. Hayes-Roth, B., and Hayes-Roth, F. Cognitive processes in planning. Cognitive Science, 1979, Vol. 3, 275-310. Also issued as Rand Report R-2366-ONR, 1979.

24. Hayes-Roth, B., Hayes-Roth F., Rosenschein, S., and Cammarata, S. Modeling planning as an incremental, opportunistic process. Proceedings of the 6th International Joint Conference on Artificial Intelligence, Tokyo, Japan, 1979. Also issued as Rand Note N-1178-ONR, June 1979.

25. Hayes-Roth, B., and Thorndyke, P. Integration of knowledge from text. Journal of Verbal Learning and Verbal Behavior, 1979, Vol. 18, 91-108. Also issued as Rand Paper P-6045, 1978.

26. Hayes-Roth, B., and Walker, C. Configural effects in human memory: The superiority of memory over external information sources as a basis for inference verification. Cognitive Science, 1979, Vol. 3, 119-140. Also issued as Rand Paper P-6061, 1977.

27. Hayes-Roth, F. Knowledge representation, organization, and control in large-scale pattern-based understanding systems. Proceedings of the Joint Workshop on Pattern Recognition and Artificial Intelligence, 1976.

28. Hayes-Roth, F. Organization and control of large-scale knowledge-based understanding systems. Proceedings of the International Symposium on Pattern Recognition and Artificial Intelligence, I.E.E.E., New York, 1976.

29. Hayes-Roth, F. Patterns of induction and related knowledge acquisition algorithms. In C. Chen (ed.), Pattern recognition and Artificial Intelligence, Academic Press, New York, 1976.

30. Hayes-Roth, F. The representation of structured events and efficient procedures for their recognition. Pattern Recognition, 1976, Vol. 8, 141-150.

31. Hayes-Roth, F. Critique of Turvey's "Contrasting orientations to the theory of visual information processing." Psychological Review, 1977, Vol. 84, 531-535.

32. Hayes-Roth, F. Uniform representations of structured patterns and an algorithm for the induction of contingency-response rules. Information and Control, 1977, Vol. 33, 87-116.

33. Hayes-Roth, F. Learning by example. In A. Lesgold, J. Pellegrino, S. Fokkema, and R. Glaser (eds.), Cognitive psychology and instruction, Plenum, New York, 1978. Also issued as Rand Paper P-5835.

34. Hayes-Roth, F. The role of partial and best matches in knowledge systems. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems, Academic Press, New York, 1978.

35. Hayes-Roth, F. Learning structured patterns. In Radar Image Analysis, Proceedings of a Workshop, New Orleans, Louisiana, February 1979.

36. Hayes-Roth, F. Syntax, semantics, and pragmatics in speech understanding systems. In W. Lea (ed.), Trends in speech recognition, Prentice-Hall, Englewood Cliffs, New Jersey, 1979.

37. Hayes-Roth, F., and Burge, J. Characterizing syllables as sequences of machine-generated labelled segments of connected speech: A study in symbolic pattern learning using a conjunctive feature learning and classification system. Proceedings of the Third Internationa' Joint Conference on Pattern Recognition, Coronado, California, 1976.

38. Hayes-Roth, F., Erman, L. D., Fox, M., and Mostow, D. J. Syntactic processing in Hearsay-II. Speech understanding systems: Summary of results of the five-year research Effort. Department of Computer Science, Carnegie-Mellon University, 1976.

39. Hayes-Roth, F., Fox, M., Gill, G., and Mostow, D. J. Semantics and pragmatics in the Hearsay-II speech understanding system. Speech understanding systems: Summary of results of the five-year research effort. Department of Computer Science, Carnegie-Mellon University, 1976.

40. Hayes-Roth, F., Gill, G., and Mostow, D. J. Discourse analysis and task performance in the Hearsay-II speech understanding system. Speech understanding systems: Summary of results of the five-year research effort. Department of Computer Science, Carnegie-Mellon University, 1976.

41. Hayes-Roth, F., Klahr, P., Burge, J., and Mostow, J. Machine methods for acquiring, learning, and applying knowledge. Rand Paper P-6241, October 1978.

42. Hayes-Roth, F., Klahr, P., and Mostow, D. Knowledge acquisition, knowledge programming, and knowledge refinement. Rand Report R-2540-NSF, 1979.

43. Hayes-Roth, F., and Lesser, V. R. Focus of attention in a distributed logic speech understanding system. Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing, 1976, 416-420.

44. Hayes-Roth, F., and Lesser, V. R. Focus of attention in the Hearsay-II system. Proceedings of the Fifth International Joint Conference on Artificial Intelligence, 1977.

45. Hayes-Roth, F., Lesser, V., Mostow, D. J., and Erman, L. D. Policies for rating hypotheses, halting, and selecting a solution in the Hearsay-II speech understanding system. Speech understanding systems: Summary of results of the five-year research effort. Department of Computer Science, Carnegie-Mellon University, 1976.

46. Hayes-Roth, F., and McDermott, J. Learning structured patterns from examples. Proceedings of the Third International Joint Conference on Pattern Recognition, Coronado, California, 1976.

47. Hayes-Roth, F., and McDermott, J. Knowledge acquisition from structural descriptions. Proceedings of the Fifth International Joint Conference on Artificial Intelligence, 1977.

48. Hayes-Roth, F., and McDermott, J. An interference matching technique for inducing abstractions. Communications of the ACM, 1978, Vol. 21, No. 5, 401-411.

49. Hayes-Roth, F., and Mostow, D. J. An automatically compilable recognition network for structured patterns. Proceedings of the Fourth International Joint Conference on Artificial Intelligence, 1975.

50. Hayes-Roth, F., and Mostow, D. J. Organization and control of syntactic, semantic, inferential and world knowledge for language understanding. Proceedings of International Conference on Computational Linguistics, 1976.

51. Hayes-Roth, F., and Mostow, D. J. Syntax and semantics in a distributed logic speech understanding system. Proceedings of the I.E.E.E. International Conference on Acoustics, Speech and Signal Processing, 1976, 421-424.

52. Hayes-Roth, F., Mostow, D. J., and Fox, M. Understanding speech in the Hearsay-II system. In L. Bolc (ed.), Natural language communication with computers, Springer-Verlag, Berlin, 1977.

53. Hayes-Roth, F., and Waterman, D. An overview of pattern-directed inference systems. Rand Paper P-6193, 1978.

54. Hayes-Roth, F., Waterman, D. A., and Lenat, D. Principles of pattern-directed inference systems. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems, Academic Press, New York, 1978.

55. Hayes-Roth, F., and Wesson, R. Distributed intelligence systems for situation assessment. Proceedings of the Workshop on Distributed Sensor Nets, Carnegie-Mellon University, Pittsburgh, 1978.

56. Hayes-Roth, F., and Wesson, R. Dynamic planning: Searching through time and space. Rand Paper P-6266, 1978.

57. Hobard, D. V., and Goldin, S. E. Selective processing in encoding and memory: An analysis of resource allocation by kindergarten children. Journal of Experimental Child Psychology, Vol. 27, 1979, 87-95.

58. Kellogg, C., Klahr, P., and Travis, L. A deductive capability for data management. In P. C. Lockman and E. J. Neuhold (eds.), Systems for large data bases, Amsterdam, 1976, 181-196.

59. Kellogg, C., Klahr, P., and Travis, L. Creating inference plans for deductive access to relational data bases. Proceedings Workshop on Logic and Data Bases, Centre D'Etudes et de Recherches de Toulouse, France, 1977.

60. Kellogg, C., Klahr, P., and Travis, L. Deductive methods for large data bases. Proceedings Fifth International Joint Conference on Artificial Intelligence, Massachusetts Institute of Technology, Cambridge, 1977, 203-209.

61. Kellogg, C., Klahr, P., and Travis, L. Deductive planning and pathfinding for relational data and bases. In H. Gallaire and J. Minker (eds.), Logic and data bases, Plenum, New York, 1978, 179-200.

62. Klahr, P. Partial proofs and partial answers. Proceedings of the Fourth Workshop on Automated Deduction, 1979, 115-121. Also issued as Rand Paper P-6239, 1978.

63. Klahr, P. Planning techniques for rule selection in deductive question-answering. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems, Academic Press, New York, 1978, 223-239.

64. Lenat, D. B., Hayes-Roth, F., and Klahr, P. Cognitive economy in artificial intelligence systems. Proceedings of the 6th International Joint Conference on Artificial Intelligence, Tokyo, Japan, 1979.

65. Lesser, V. R., Hayes-Roth, F., Birnbaum, M., and Cronk, R. Selection of word islands in the Hearsay-II speech understanding system. Proceedings of the I.E.E.E. International Conference on Acoustics, Speech and Signal Processing, 1977.

66. McDonald, D., and Hayes-Roth, F. A semantic network inferential approach to the design of an extensible language understanding system. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems, Academic Press, New York, 1978.

67. Miller, J., and Hayes-Roth, B. Text annotation: A technique for facilitating knowledge integration. Rand Paper P-6054, 1977.

68. Mohs, R. C., and Wescourt, K. T. Processing multiple recognition probes in short- and long-term memory. Bulletin of the Psychonomic Society, 1975, Vol. 5, 319-322.

69. Mohs, R. C., Wescourt, K. T., and Atkinson, R. C. Search processes for associative structures in long-term memory, Journal of Experimental Psychology: General, 1975, Vol. 104, 103-121.

70. Mostow, D. J., and Hayes-Roth, F. A production system for speech understanding. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems, Academic Press, New York, 1978.

71. Mostow, J., and Hayes-Roth, F. Machine-aided heuristic programming: A paradigm for knowledge engineering. Rand Note N-1007, February 1979.

72. Mostow, J., and Hayes-Roth, F. Operationalizing heuristics: Some AI methods for assisting AI programming. Proceedings of the 6th International Joint Conference on Artificial Intelligence, Tokyo, Japan, 1979.

73. Reitman, J. S., and McArthur, D. J. Is computer chess like human chess? A review of P. Frey's Computer skill in man and machine. Contemporary Psychology, 1979, Vol. 24, No. 6.

74. Shoben, E. J., Wescourt, K. T., and Smith, E. E. Sentence verification, sentence recognition, and the semantic/episodic distinction, Journal of Experimental Psychology: Human Learning and Memory, 1978, Vol. 4, 304-317.

75. Stevens, A., Collins, A., and Goldin, S. E. Misconceptions in students' understanding. International Journal of Man-Machine Studies, 1979.

76. Thorndyke, P. Cognitive structures in human story comprehension and memory. Rand Paper P-5513, 1975.

77. Thorndyke, P. Conceptual complexity and imagery in comprehension and memory. Journal of Verbal Learning and Verbal Behavior, 1975, Vol. 14, 359-369.

78. Thorndyke, P. The role of inferences in discourse comprehension. Journal of Verbal Learning and Verbal Behavior, 1976, Vol. 15, 437-446.

79. Thorndyke, P. Cognitive structures in comprehension and memory of narrative discourse. Cognitive Psychology, 1977, Vol. 9, 77-110.

80. Thorndyke, P. Knowledge acquisition from newspaper stories. Discourse Processes, Vol. 2, 1979, 95-112. Also issued as Rand Paper P-6065-1, 1977.

81. Thorndyke, P. Knowledge transfer in learning from texts. In A. Lesgold, J. Pellegrino, S. Fokkema, and R. Glaser (eds.), Cognitive psychology and instruction, Plenum, New York, 1978, 91-100. Also issued as Rand Paper P-5773, February 1977.

82. Thorndyke, P. Pattern-directed processing of knowledge from texts. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems, Academic Press, New York, 1978. Also issued as Rand Paper P-5806.

83. Thorndyke, P. Research on connected discourse--A general bibliography: 1900-1977. Rand Paper P-6131, 1978.

84. Thorndyke, P. Heuristics for human knowledge acquisition from maps. Proceedings of the 6th International Joint Conference on Artificial Intelligence, Tokyo, Japan, 1979. Also issued as Rand Note N-1193-ONR, July 1979.

85. Thorndyke, P., and Hayes-Roth, B. The use of schemata in the acquisition and transfer of knowledge. Cognitive Psychology, 1979, Vol. 11, 82-106. Also issued as Rand Paper P-6046, 1977.

86. Thorndyke, P., and Stasz, C. Individual differences in knowledge acquisition from maps. Rand Report R-2375-ONR, 1979.

87. Thorndyke, P., and Stasz, C. Strategies for map learning. Rand Paper P-6311, 1979.

88. Thorndyke, P., and Yekovich, F. A critique of schemata as a theory of human story memory. Poetics, 1980, Vol. 9, 23-48. Also issued as Rand Paper P-6307, 1979.

89. Veit, C. Comment on internal feedback as a theory of judgment: A reply to Levin. Journal of Experimental Psychology: General, 1978, Vol. 107, No. 1, 112-114.

90. Veit, C. Ratio and subtractive processes in psychophysical judgment. Journal of Experimental Psychology: General 1978, Vol. 107, 81-107.

91. Waterman, D. A. Adaptive production systems. Proceedings of the Fourth International Joint Conference on Artificial Intelligence, 1975, 296-303.

92. Waterman, D. A. Serial pattern acquisition: A production system approach. In C. H. Chen (ed.), Pattern recognition and Artificial Intelligence, Academic Press, New York, 1976.

93. Waterman, D. A. Exemplary programming in RITA. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems. Academic Press, New York, 1978. Also issued as Rand Paper P-5861, May 1977.

94. Waterman, D. A. An introduction to production systems. Artificial Intelligence and Simulation of Behavior Newsletter, Issue 25, January, 1977. Also issued as Rand Paper P-5751.

95. Waterman, D. A. A rule-based approach to knowledge acquisition for man-machine interface programs. International Journal of Man-Machine Studies, 1978, Vol. 10, 693-711. Also issued as Rand Paper P-5823, 1978.

96. Waterman, D. A. Rule-directed interactive transaction agents: An approach to knowledge acquisition. Rand Report R-2171, 1978.

97. Waterman, D. A., Anderson, R. H., Hayes-Roth, F., Martins, G. R., and Rosenschein, S. J. Design of a rule-oriented system for implementing expertise. Rand Note N-1158, 1979.

98. Waterman, D. A., and Hayes-Roth, F. An overview of pattern-directed inference systems. In D. A. Waterman and F. Hayes-Roth (eds.), Pattern-directed inference systems, Academic Press, New York, 1978.

99. Waterman, D. A., and Hayes-Roth, F. (eds.). Pattern-directed inference systems, Academic Press, New York, 1978.

100. Waterman, D. A., and Jenkins, B. Heuristic modeling using rule-based computer systems. Rand Paper P-5811, 1976.

101. Waterman, D. A., and Newell, A. PAS-II: An interactive task-free version of an automatic protocol analysis system. IEEE Transactions, 1976, 402-413.

102. Wescourt, K. T., and Atkinson, R. C. Fact retrieval processes in human memory. In W. K. Estes (ed.), Handbook of learning and cognitive psychology, Vol. 4, Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1976.

103. Wescourt, K. T., Beard, M., and Gould, L. Knowledge-based adaptive curriculum sequencing for CAI: Application of a network representation. Technical Report No. 288, Institute for Mathematical Studies in the Social Sciences, Stanford University, September 1977. Also in Proceedings of the ACM Annual Conference, 1977.

104. Wescourt, K. T., Beard, M., Gould, L., and Barr, A. Knowledge-based CAI: CINs for individualized curriculum sequencing. Technical Report No. 290, Institute for Mathematical Studies in the Social Sciences, Stanford University, October 1977.

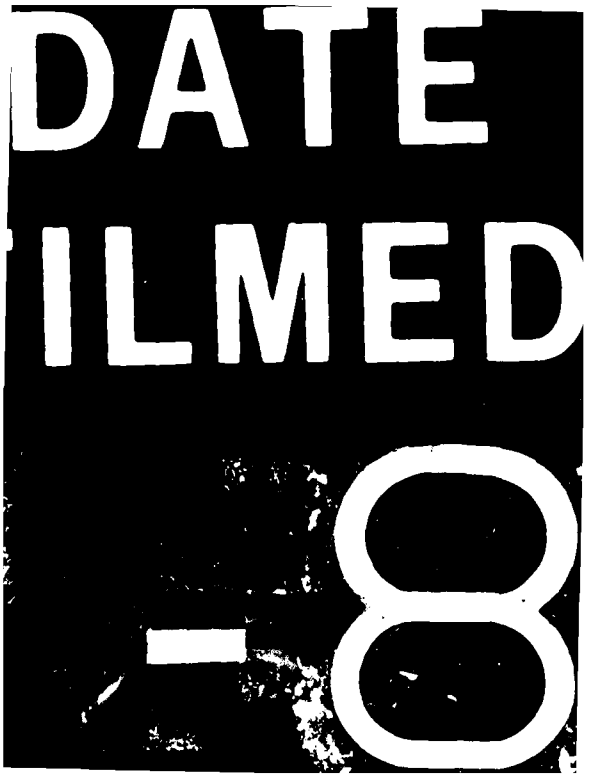
105. Wescourt, K. T., and Hemphill, L. Representing and teaching knowledge for troubleshooting/debugging. Technical Report No. 292, Institute for Mathematical Studies in the Social Sciences, Stanford University, February 1978. Also in IEEE Transactions, 1976, 402-413.

106. Wesson, R. Planning in the world of the air traffic controller. Proceedings of the IJCAI, 1977.

107. Wesson, R., and Hayes-Roth, F. Dynamic planning: Searching through time and space. Rand Paper P-6266, February 1979.

108. Wesson, R., and Hayes-Roth, F. A network simulation for distribution assessment. Proceedings of the IEEE Transactions Systems, Man & Cybernetics, Denver, Colorado, 1979.

AUTHOR INDEX


DATE
ILMED
8